DISCONTINUOUS TRANSMISSION CONTROLLER APPARATUS AND METHOD

BACKGROUND OF THE INVENTION

5

I. Field of the Invention

The present invention pertains generally to the field of wireless data communications, and more specifically to a method and apparatus for
10 controlling vocoder frame generation in a discontinuous transmission communication system.

II. Background

15 Wireless communications have become commonplace in much of the world today. In many digital wireless communication systems, audio information, typically voice, is transmitted between wireless communication devices and other end units via infrastructure equipment. Examples of various communication systems include code division multiple access (CDMA)
20 systems, global system for mobile communications (GSM) systems, wideband code division multiple access (WCDMA) systems, as well as others.

In many wireless communication systems, human speech is converted into electronic signals and digitized. The digitized speech is often provided to a vocoder, which is a well known device in the art for compressing the digitized
25 speech signal for efficient wireless transmission. The output of the vocoder comprises vocoder frames, which are discreet "packages" of bits representing the compressed digitized speech. Vocoders may operate using either fixed or variable rate encoding techniques, both of which are well known in the art. In either case, vocoders operate to take advantage of natural pauses, or lapses,
30 inherent in human speech to provide bandwidth compression. In some communication systems using fixed rate vocoders, vocoder frames are not transmitted during periods of speech inactivity, thereby reducing the bandwidth necessary for the communication.

Several problems are inherent in the fixed rate vocoder application.
35 First, the transition from periods of speech activity to periods of speech inactivity may be noticeable to users. Another problem is that the background noise inherent in most telephonic communications is not preserved as the communication transitions from periods of speech activity to periods of speech inactivity. These problems are exacerbated in communication systems

employing secure communication techniques, such as public key encryption techniques.

In a fixed rate vocoder application, it would be desirable to preserve the background noise during such transitions so that users do not perceive noticeable sound quality differences.

SUMMARY OF THE INVENTION

The present invention is directed to a discontinuous transmission controller method and apparatus. In one embodiment, the present invention is directed to an apparatus comprising a vocoder for generating vocoder frames from said digitized audio signal at a predetermined output rate if speech is present, for generating no vocoder frames during periods of speech inactivity, and for generating transition frames during transitions from speech activity to speech inactivity, the transition frames comprising background noise information.

In another embodiment, the present invention is directed to a method comprising the steps of determining a voice activity level in a digitized audio signal, and generating vocoder frames at a predetermined rate in a transmitter if speech activity is present. In no speech activity is detected, no vocoder frames are generated. During a transition period between speech activity and speech inactivity, transition frames are generated, the transition frames comprising background noise information.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a functional block diagram of a typical terrestrial wireless communication system employing the embodiments of the present invention;

FIG. 2 illustrates a functional block diagram of a portion of a transmitter used in an exemplary wireless communication device (WCD) of the communication system in FIG. 1;

FIG. 3 is a functional block diagram of a prior art fixed-rate vocoder;

FIG. 4 illustrates one embodiment of the basic concept of the method and apparatus for controlling a discontinuous transmission process;

FIG. 5 illustrates a fixed-rate vocoder using a rate detector to determine voice activity;

FIG. 6 illustrates a second embodiment of controlling the discontinuous transmission process;

FIG. 7 illustrates a transmitter comprising an encryption module for transmitting secure communications;

FIGs. 8a, 8b, and 8c illustrate the relationship between vocoder frames and a state vector as used in the transmitter of FIG. 7;

FIG. 8a illustrates a sequential series of vocoder frames and a value of a state vector generated;

FIG. 9 is a functional block diagram of a receiver used to decode vocoder frames from a transmitter using the discontinuous transmission method and apparatus using cryptographic techniques;

FIG. 10 is a flow diagram illustrating a method of controlling a discontinuous transmission process as used in a transmitter, referencing the vocoder of FIG. 5;

FIG. 11 is a flow diagram illustrating a method of controlling a discontinuous transmission process as used in the transmitter of FIG. 7; and

FIG. 12 is a flow diagram illustrating a method of controlling a discontinuous transmission process as used in the receiver of FIG. 9.

DETAILED DESCRIPTION

The embodiments described herein are described with respect to a terrestrial wireless communication system. However, it should be understood that the present invention may be used in any communication system which uses vocoders to reduce the transmission bandwidth of information. Such communication systems comprise the many variations of digital communication systems found today, including code division multiple access (CDMA) systems, global system for mobile communications (GSM) systems, wideband code division multiple access (WCDMA) systems, and others.

A functional block diagram of a typical terrestrial wireless communication system **100** employing the embodiments of the present invention is shown in FIG. **1**. Wireless communication devices (WCDs) **102** send and receive wireless transmissions to other wireless communication devices **102** through base station transceiver(s) **110** and base station controller **112**, to landline communication devices **104** using public switched telephone network (PSTN) **114**, to satellite communication devices **106** using gateway **116**, or to data communication devices **108** over data network **118**. In one embodiment, WCDs **102** and satellite communication devices **106** comprise wireless telephones, while landline communication devices **104** comprise

landline telephones and data communication devices **108** comprise digital modems in conjunction with an analog telephone.

FIG. **2** illustrates a functional block diagram of a portion of transmitter **200** used in an exemplary WCD **102**. Audio information, such as human speech,

5 is received by analog-to-digital (A/D) converter **202**. Typically, the audio information additionally comprises background noise. The audio information is converted into a digitized electronic signal by A/D **202**. The process of such a conversion is well known in the art. The digitized audio information is then provided to vocoder **204**.

10 Vocoder **204** is responsible for compressing the digitized audio information to minimize the bandwidth necessary for transmission. The output of vocoder **204** comprises vocoder frames, which are discreet packages of information representing the compressed digitized speech. Vocoders may operate using either fixed or variable rate encoding techniques, both of which

15 are well known in the art. In systems using variable-rate vocoders, bandwidth efficiency is achieved by encoding the digitized audio information in one of a number of different encoding rates, each encoding rate representative of the level of speech activity present in the audio information.

An example of a variable-rate vocoder is found in United States patent

20 number 5,414,796 (the '796 patent) entitled "VARIABLE RATE VOCODER", assigned to the assignee of the present invention and incorporated by reference herein. The '796 patent describes a variable-rate vocoder having four encoding rates: a first encoding rate for encoding audio information during periods of active speech, a second and third encoding rates each successively less than the

25 previous encoding rates for encoding the audio information during transitions between active speech and inactive speech, and a fourth encoding rate for encoding the audio information at a rate lower than the other three rates for encoding audio information during periods of no or low speech activity.

The statistical characteristics of a speech signal can be demonstrated by

30 what is generally known as a source-filter model. Speech data can be significantly compressed with this type of modeling. Thus, a communication channel can be efficiently used for more transmission. The source-filter model assumes that speech is the result of exciting linear time-varying filters with a source signal. The excitation source signal is modeled as either a periodic

35 impulse train for voiced speech like vowel sounds, or a random noise for unvoiced speech like consonants. The linear time-varying filters usually include a formant synthesis filter, or a linear predictive coding (LPC) synthesis filter, and a pitch synthesis filter.

In systems using fixed-rate vocoders, vocoder frames are not generated during periods of speech inactivity, thereby reducing the bandwidth necessary for the communication. Fixed-rate vocoders are well known in the art.

In one embodiment of the present invention, vocoder **204** comprises a
5   fixed-rate vocoder which performs an analysis of the input audio information to determine a level of voice activity. A control signal is generated in response to the voice activity determination, which is used internally by vocoder **204** and is also provided to other functional blocks, such as a transmitter (not shown) and/or a processor (also not shown), to control a discontinuous transmission
10   process. The discontinuous transmission process refers to a process of disabling the transmission of vocoder frames during periods of no or low voice activity. When a low/no level of speech activity is detected by vocoder **204**, a control signal is used internally to vocoder **204**, as will be explained below. It is also used to signal other elements when to discontinue transmission.

15   Generally, vocoder frames are generated at a predetermined, fixed output rate in either the fixed-rate case or the variable-rate case. In one embodiment, vocoder frames are generated at an output rate of one frame every 20 milliseconds. The vocoder frames are next provided to modulator **206**. Modulator **206** modulates the vocoder frames using the predetermined
20   modulation technique of the wireless communication system. Examples of different modulation techniques include Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), and Frequency Division Multiple Access (FDMA). Once the vocoder frames have been modulated, they are provided to RF circuitry for upconvertion and transmission.

25   FIG. **3** is a functional block diagram of a prior art fixed-rate vocoder **204**. Audio information is provided to the front-end processing unit **300** comprising audio front-end functions such as D.C. removal and echo cancellation. The preprocessed audio information is then provided to SPEECH analysis unit **302**, where standard linear prediction analysis is performed for model parameter
30   estimation, ultimately to determine the poles in a speech synthesis filter. The preprocessed audio information is then provided to an encoder unit **304** to determine the excitation to the synthesis filter as well as to quantize parameters used to represent the audio information. Generally, each type of vocoder uses a different set of parameters to represent audio information. Table 1 shows the
35   parameters used in a traditional Mixed Excitation Linear Prediction (MELP) vocoder model.

Table 1

MELP Parameter
msvq[0]   (line spectral frequencies)
msvq[1]   (line spectral frequencies)
msvq[2]   (line spectral frequencies)
msvq[3]   (line spectral frequencies)
fsvq   (Fourier magnitudes)
gain[0]   (gain)
gain[1]   (gain)
pitch   (pitch – overall voicing)
bp   (bandpass voicing)
af   (aperiodic flag/jitter index)
sync   (sync bit)

Finally, the parameters are assembled in a vocoder frame using frame packaging unit **306**. Note that in this example the vocoder encodes data at a fixed encoding rate. Therefore, the vocoder frame size (i.e., number of bits) is
5   fixed over all speech conditions.

FIG. **4** illustrates one embodiment of the basic concept of the method and apparatus for controlling a discontinuous transmission process. In this embodiment, digitized audio information is provided to a fixed-rate vocoder. In another embodiment, a variable-rate vocoder is used. Digitized audio
10   information **400** is shown varying with respect to time. A voice activity detector is used to determine the level of speech activity in the digitized audio information using one or more voice activity detector (VAD) thresholds **402**. During periods of high voice activity above a first threshold, "active" vocoder frames are generated at a fixed encoding rate in the fixed-rate vocoder
15   application and at a full rate in the variable-rate vocoder application. This period of shown in FIG. 4 as active periods **404**.

When the voice activity level falls below a second threshold representing a low level of speech activity, or no speech activity, an "inactive" frame is generated. This period is shown in FIG. 4 as inactive period **406**. In the fixed-
20   rate vocoder application, the inactive frame is a representation of background noise encoded at the fixed encoding rate. In the variable-rate vocoder application, the inactive frame is again a representation of the background noise encoded at a minimal encoding rate. In either case, in the discontinuous communication system, inactive frames are not transmitted.

25   The transition period between periods of high voice activity to no/low voice activity is known as a "transition" period, or a "grace" period, shown as transition period **408**. During this period of time, "transition" vocoder frames are generated. The transition frames contain information relating to background noise, otherwise known as "comfort noise" for reproduction at a

receiver. Comfort noise is generated so that a user is not annoyed by the disappearance of background noise during periods of silence. The transition frames provide information to the receiver in order to maintain the background noise generated at transmitter **200**. An optional "blank" period **410** provides for

5 a minimum period of time that the vocoder is in the inactive period **406**. When voice activity again exceeds the first threshold, active vocoder frames are generated once again. In one embodiment, no transition frames are generated from transitions between inactive period **406** and active period **404**. In another embodiment, a "re-start" period **412** is defined in which transition frames are

10 generated in much the same way as transitions from active period **404** to inactive period **406**, as explained below.

FIG. **5** illustrates a fixed-rate vocoder **204** using a rate detector to determine voice activity which, in turn, controls the discontinuous transmission process. Front-end processing unit **500** and SPEECH analysis unit **502** operate

15 in the same manner as the corresponding elements in FIG. **3**. The preprocessed audio information is then provided to voice activity detector **504**. Voice activity detector **504** uses one of several well-known techniques to determine a voice activity level of the preprocessed audio information. Once the voice activity level is detected, voice detector **504** generates a control signal which is normally

20 used in a variable-rate vocoder to control the encoding rate of vocoder **204**. In the present case, the control signal does not alter the encoding rate of the fixed-rate vocoder. Rather, it is used to signal other elements of vocoder **204** when to generate active frames, inactive frames, and transition frames. The control signal is also used by other elements external to vocoder **204**, generally for the

25 purpose of enabling and disabling the transmission of vocoder frames.

In one embodiment, voice activity detector **504** determines the level of voice activity by relying on a rate decision algorithm, many of which are well known in the art. The rate decision algorithm is typically used in variable-rate vocoder applications to determine the various encoding rates to apply to audio

30 information.

One such rate decision algorithm is disclosed in U.S. Pat. No. 5,911,128, entitled "METHOD AND APPARATUS FOR PERFORMING REDUCED RATE VARIABLE RATE VOCODING," issued Jun. 8, 1999, assigned to the assignee of the present invention and incorporated by reference herein. This technique

35 provides a set of rate decision criteria referred to as mode measures. A first mode measure is the target matching signal to noise ratio (TMSNR) from the previous encoding frame, which provides information on how well the encoding model is performing by comparing a synthesized speech signal with the input speech signal. A second mode measure is the normalized

autocorrelation function (NACF), which measures periodicity in the speech frame. A third mode measure is the zero crossings (ZC) parameter, which measures high frequency content in an input speech frame. A fourth measure, the prediction gain differential (PGD), determines if the encoder is maintaining

5   its prediction efficiency. A fifth measure is the energy differential (ED), which compares the energy in the current frame to an average frame energy. Using these mode measures, a rate determination logic selects an encoding rate for a current vocoder frame. Voice activity detector **406** determines the level of voice activity from the rate determination. For example, voice activity detector **406**

10   generates a control signal indicative of high voice activity if the rate determination algorithm selects full rate encoding.

In any case, voice activity detector **504** generates a control signal based on the level of speech activity detected. In one embodiment, the control signal indicates active state when a high level of voice activity is detected, an inactive

15   state when a low level of voice activity (or none) is detected, and indicates a transition state when the voice activity transitions from a high level to a low level (or none). In anther embodiment, transition frames are also generated during transitions from the inactive state to the active state. For example, in the four-encoding-rate example provided in the '796 patent, a full encoding rate

20   corresponds to a high level of voice activity while the eighth encoding rate corresponds to a low/no level of voice activity. The half and fourth encoding rates are used as flags to help smooth the transition from active speech to no/low speech. The control signal is provided to a parameter modification unit **508** within vocoder **204**.

25   Encoder unit **506** receives the preprocessed audio information from voice activity detector **504** and performs an analysis of the audio information as explained above with respect to encoder unit **304** to determine the excitation to the synthesis filter as well as to quantize parameters used to represent the audio information. The parameters are then provided to parameter modification unit

30   **508**. Parameter modification unit **508** receives the parameters from encoder unit **506** and the control signal from voice activity detector **504**. If the control signal indicates a transition from high to no/low levels of voice activity, steps are taken so that parameter smoothing can take place. For example, the lsp and gain parameters are modified to include a background noise estimate. This is

35   used at the decoder to generate the comfort noise which is equivalent to the ambient noise at the encoder.

Finally, the parameters are assembled in a vocoder frame using frame packaging unit **510**. In a variable-rate vocoder application, the control signal

from voice activity detector is also provided to packaging unit **510** to determine the number of bits to include in each vocoder frame.

FIG. **6** illustrates a second embodiment of controlling the discontinuous transmission process. In this embodiment, the voice activity detector **506** of FIG. **5** is replaced by a background noise suppression element **606** to determine voice activity instead of voice activity detector **506**. All other functional blocks shown in FIG. **6** operate in a similar way to the functional blocks of FIG. **5**.

Background noise suppression element **606** provides a control signal based upon detection and suppression of background noise, such as undesired noise from automobile traffic, wind, crowds, and so on. One example of such a noise suppressor is found in U.S. patent number 6,122,384 (the '384 patent) entitled "NOISE SUPPRESSION SYSTEM AND METHOD", assigned to the assignee of the present invention and incorporated by reference herein.

Typically, noise suppression element **606** generates a control signal having two states: an encode state and a disable state. The control signal is provided to parameter modification unit **610** so that parameter modification during transition periods can take place. The noise suppression element described by the '384 patent comprises a rate decision element used to determine the level of voice activity. The rate decision element may be used by noise suppression element **606** to determine when to transition between states. In another embodiment, the rate decision element provides a control signal directly to parameter modification unit **608**.

The control signal from voice activity detector **506** or noise suppression unit **604** can be used in elements other than vocoder **204** to further control the discontinuous transmission process. For example, FIG. **7** illustrates a transmitter **700** comprising encryption module **710**. Such a transmitter is used to safeguard voice or data communications from unauthorized third parties using techniques such as public key encryption.

As before, audio information is received by A/D **702** and converted into a digitized signal. The digitized signal is provided to vocoder **704**, where vocoder frames are generated from the digitized signal. Vocoder **704** generates vocoder frames for each of the three defined voice activity states: active, inactive, or transition, and provides them to an optional memory **706**. Memory **706** typically comprises one or more random access memories (RAM). Memory **706** may also be segregated into a "clear" portion and an encrypted portion. The clear portion is used to store vocoder frames prior to encryption. After vocoder frames are encrypted, they may be stored in memory **706**, however, special security measures ensure that no encrypted vocoder frames are allowed to be co-mingled with clear vocoder frames. Vocoder **704** also provides a

control signal to switch **708** and to state vector generator **710** to achieve discontinuous transmission.

Encryption module **712** is responsible for encrypting each vocoder frame with a unique code, or codebook. Generally, one codebook is generated for
5 each data frame to be encrypted, generally at the same rate that frames are generated by vocoder **704**. Therefore, one codebook is generally available for each data frame to be encrypted. Other techniques allow two vocoder frames to encrypted with one codebook, the codebook having twice as many bits as one vocoder frame.

10 The codebook is created using one of several well-known techniques. Among them are the Data Encryption Standard (DES), FEAL, and the International Data Encryption Algorithm (IDEA). In one embodiment of the present invention, DES is used to create codebooks, using a state vector along with one or more encryption keys, as shown in FIG. 7. The state vector is, in its
15 simplest form, a counting sequence, incrementing at a predetermined rate, generally equal to a multiple of the rate at which vocoder frames are generated by vocoder **704**. The state vector is generated by state vector generator **710**, using well known techniques, such as discrete electronic components, or a digital microprocessor in combination with a set of software instructions. Other
20 techniques well known in the art are also contemplated.

Encryption module **712** produces one codebook every time state vector generator **710** is incremented. Each codebook produced is digitally combined with one vocoder frame stored in memory **706**, generally in the order that the vocoder frames were stored in memory **706**, to produce one encrypted data
25 frame for every vocoder frame provided to encryption module **712**. Codebooks are combined with vocoder frames using well-known techniques, such as adding one vocoder frame to one codebook using modulo-2 arithmetic. In another embodiment, 2 vocoder frames are added to a single codebook, the codebook in this embodiment having twice the number of bits as a single
30 vocoder frame.

One problem using the encryption method in conjunction with the discontinuous transmission process as described above is that the discontinuous transmission process causes discontinuities in the encrypted frames generated by encryption module **712**. Discontinuities result from the state vector
35 generated by state vector generator **710** incrementing at a time at which inactive frames are generated during periods of no/low voice activity. During this time, the control signal from vocoder **704** opens switch **708** to prevent inactive frames from being encrypted. This problem is best illustrated in FIGs. 8a, 8b, and 8c.

FIG. 8a illustrates a sequential series of vocoder frames numbered one through six and the value of the state vector generated by state vector generator **710** corresponding to each vocoder frame. In one embodiment, vocoder frames are generated at a constant output rate of one frame every 20 milliseconds by vocoder **704**. Each vocoder frame may be stored briefly in memory **706** prior to use by encryption module **712**. In an alternative embodiment, vocoder frames are provided directly to encryption module **712**. In either case, vocoder frames are provided to encryption module **712** via switch **708** at the same rate that vocoder **704** produces vocoder frames. State vector generator **710** is incremented at the predetermined rate, generally a multiple of the rate at which vocoder frames are generated by vocoder **704**.

In FIG. 8a, vocoder frame 1 is encoded by encryption module **712**, using a codebook derived from state vector 1. Frame 2 is next encoded, using a codebook derived from state vector 2. Frame 3 is next encoded, using a codebook derived from state vector 3, and so on. In a receiver, the encrypted vocoder frames are decrypted using a state vector which is synchronized to frames being encrypted at transmitter **700**. In other words, vocoder frame 1, which was encrypted using a codebook derived from state vector 1, is decrypted using a codebook derived from a state vector equal to 1. Vocoder frame 2 is decrypted using a codebook derived from a state vector equal to 2, and so on.

FIG. 8b illustrates a problem of the encryption process of FIG. 7a when an inactive vocoder frame is generated by vocoder **704**. As before, vocoder frames 1 through 6 are shown in sequence as generated by vocoder **704**. First, an active vocoder frame 1 is generated and encoded by encryption module **712** (with or without the use of memory **706**) using a codebook derived from state vector 1. Next, an active vocoder frame 2 is generated by vocoder **204** and then encrypted using a codebook derived from state vector 2. Next, frame 3 is generated by vocoder **704**, however, in this example, frame 3 is an inactive vocoder frame. The control signal from vocoder **704** opens switch **708** so that the inactive vocoder frame is not encrypted by encryption module **712**. The inactive frame is generally over-written in memory **706** with frame 4 in the following 20 millisecond time interval. If state vector generator **710** is allowed to continue to increment, a codebook resulting from state vector 3 is generated, but because a vocoder frame has not been provided to encryption module **712**, an encrypted frame is not generated. Next, vocoder frame 4 is generated and encrypted using a codebook derived from state vector 4.

At a receiver, vocoder frame 1 is received and decrypted using a codebook derived from state vector 1. Vocoder frame 2 is then decrypted using

a codebook derived from state vector 2. The next frame received is vocoder frame 4, because vocoder frame 3 was not encrypted or transmitted. When vocoder frame 4 is decrypted using a codebook derived from state vector 3, unintelligible data results, because vocoder frame 4 was encrypted using a

5 codebook derived from a state vector equal to 3.

In this embodiment, when an inactive vocoder frame is generated by vocoder **704**, state vector generator **710** is disabled by the control signal from vocoder **704** so that a state vector is not incremented during times when inactive frames are generated. This is illustrated in FIG. 8c.

10 As shown in FIG. 8c, vocoder frames 1 through 6 are generated by vocoder **704**. However, in this example, vocoder frames 3, 4, and 5 comprise inactive frames. Vocoder frame 1 is encoded using a codebook derived from state vector 1. Vocoder frame 2 is encoded using a codebook derived from state vector 2. When voice activity drops to a low threshold, inactive vocoder frames

15 3, 4, and 5 are generated by vocoder **704**. Vocoder **704** sends a control signal to state vector generator **710**, disabling the state vector generator from incrementing for the duration of frames 3, 4, and 5. Switch **708** is also opened to prevent the inactive frames from being encrypted. When voice activity is detected once again, the control signal from vocoder **704** enables state vector

20 generator to resume its count, in this example, to a value of 3. Therefore, vocoder frame 6 is encrypted using a codebook derived from state vector 3.

At the receiver, vocoder frame 1 is received and decrypted using a codebook derived from a state vector equal to 1. Vocoder frame 2 is decrypted using a codebook derived from a state vector equal to 2. The next frame to be

25 received is vocoder frame 6, since vocoder frames 3, 4, and 5 were not transmitted. Vocoder frame 6 is decrypted using a codebook derived from a state vector equal to 3, which is the state vector used to encode this frame at transmitter **700**. As one can see, this method preserves the crypto-synchronization between transmitter **700** and a receiver.

30 FIG. **9** is a functional block diagram of a receiver **900** used to decode vocoder frames from a transmitter using the discontinuous transmission method and apparatus as described above using cryptographic techniques. Note that not all functional blocks comprising receiver **900** are shown in FIG. **9** for purposes of clarity. In FIG. **9**, the upconverted signal is received by RF

35 receiver **902** using techniques well known in the art. The upconverted signal is downconverted then provided to demodulator **904**, where the downconverted signal is converted into vocoder frames. The generation of vocoder frames may involve other processing apparatus and steps which are not shown in FIG. **9**.

The vocoder frames are then stored in receive buffer **906** for use by decryption module **908**. Receive buffer **906** is shown being partitioned into a clear portion and a secure portion. Vocoder frames arriving from demodulator **904** and prior to decryption are secure and stored in the secure portion of receive buffer **906**. After vocoder frames have been decrypted by decryption module **908**, they are stored in the clear section of receive buffer **906**. Of course, two or more independent buffers could be used in the alternative.

Decryption module **908** is responsible for decrypting each vocoder frame stored in receive buffer **906** with a unique codebook, similar to the technique used to encrypt data frames as discussed above. Generally, one codebook is generated for each vocoder frame to be decrypted, generally at the same rate that frames are generated by vocoder **704** at transmitter **700**. Therefore, one codebook is generally available for each vocoder frame to be decrypted. Other techniques allow two vocoder frames to decrypted with one codebook, the codebook having twice as many bits as one vocoder frame.

In one embodiment, a state vector is used to generate the codebook, along with one or more decryption keys. The state vector in FIG. **9**, like the state vector in transmitter **700**, is a counting sequence, incrementing at the same predetermined rate as the state vector at transmitter **700**. The state vector is generated by state vector generator **910**, using well known techniques, such as discrete electronic components, or a digital microprocessor in combination with a set of software instructions. Other techniques well known in the art are also contemplated.

Decryption module **908** produces one codebook for every state vector that is provided to it from state vector generator **910**. Vocoder frames stored in receive buffer **906** are provided to decryption module **908** in sequence, where a unique codebook derived from the current state vector is digitally combined with each vocoder frame to produce decrypted vocoder frames. Codebooks are combined with data frames using well-known techniques, such as adding one data frame to one codebook, using modulo-2 arithmetic. In another embodiment, 2 data frames are combined with a single codebook, the codebook in this embodiment having twice the number of data bits as a single vocoder frame.

After the decrypted vocoder frames are generated by decryption module **908**, they are stored in receive buffer **906** until needed by vocoder **912**. Vocoder **912** requires a constant stream of vocoder frames in order to accurately reproduce the original data transmitted by transmitter **700**.

The coordination of the above processes is generally handled by processor **914**. Processor **914** can be implemented in one of many ways which

are well known in the art, including a discreet processor or a processor integrated into a custom ASIC. Alternatively, each of the above block elements could have an individual processor to achieve the particular functions of each block, wherein processor **914** would be generally used to coordinate the

5   activities between the blocks.

Vocoder frames are not received by receiver **900** on a regular basis, due to the discontinuous nature of the transmitter during periods of inactive voice activity. When transmissions have been discontinued for a relatively long amount of time, the number of encrypted vocoder frames available for

10   decryption is depleted from receiver buffer **906**. When receiver buffer **906** is depleted, processor **914** instructs vocoder **912** to generate comfort noise as specified by the last few vocoder frames successfully processed. Remember, a transmission discontinuity is preceded by several transition vocoder frames. The last few frames to be processed prior to a transmission discontinuation at

15   transmitter **700** comprise these transition frames. The transition frames, as explained above, contain information pertaining to the background noise estimation occurring at transmitter **700** just prior to a transmission discontinuation. Vocoder **912** uses the information contained in the transition frames to generate a continuous series of vocoder frames similar to the

20   transition frames so that the output of vocoder **912** is not interrupted.

Immediately after receive buffer **906** is depleted of encrypted vocoder frames, processor **914** sends a signal to state vector generator to disable further incrementation of the state vector. When vocoder frames once again become available for decryption in receiver buffer **906**, processor **914** re-enables state

25   vector generator so that the state vector can increment in synchronization with the newly received vocoder frames provided to decryption module **908**.

FIG. **10** is a flow diagram illustrating a method of controlling a discontinuous transmission process as used in a transmitter, referencing the vocoder of FIG. **5**. In step **1000**, digitized audio information is received by

30   front-end processing unit **500** comprising audio front-end functions such as D.C. removal and echo cancellation. The preprocessed audio information is then provided to speech analysis unit **502** in step **1002**, where, in one embodiment, standard linear prediction analysis is performed for model parameter estimation, ultimately to determine the poles in a speech synthesis

35   filter. In other encoding schemes, other kinds of analysis is performed to determine the pertinent information needed to perform speech modeling.

In step **1004**, the preprocessed audio information is received by voice activity detector **504**. Voice activity detector **504** uses one of several well-known techniques to determine a voice activity level of the preprocessed audio

information. Once the voice activity level is detected, voice detector **504** generates a control signal which is used to signal other elements of vocoder **204** when to generate active frames, inactive frames, and transition frames.

The control signal is based on the level of speech activity detected. In one embodiment, the control signal indicates an active state when a high level of voice activity is detected, an inactive state when a low level of voice activity (or none) is detected, and indicates a transition state when the voice activity transitions from a high level to a low level (or none). The transition state is used to help smooth the transition from active speech to no/low speech. The control signal is provided to a parameter modification unit **508**.

In step **1006**, encoder unit **506** receives the preprocessed audio information from voice activity detector **504** and performs an analysis of the audio information to determine the excitation to the synthesis filter as well as to quantize parameters used to represent the audio information.

The parameters are then provided to parameter modification unit **508** in step **1008**. Parameter modification unit **508** receives the parameters from encoder unit **506** and the control signal from voice activity detector **504**. If the control signal indicates a transition from high to no/low levels of voice activity, steps are taken so that parameter smoothing can take place. For example, the lsp and gain parameters are modified to include a background noise estimate. This is used at the decoder to generate the comfort noise which is equivalent to the ambient noise at the encoder. In one embodiment, no modifications to the parameters are necessary if the control signal indicates active speech or inactive speech.

Finally, in step **1010**, the parameters are assembled in a vocoder frame using frame packaging unit **510**. In a variable-rate vocoder application, the control signal from voice activity detector is also provided to packaging unit **510** to determine the number of bits to include in each vocoder frame.

FIG. **11** is a flow diagram illustrating a method of controlling a discontinuous transmission process as used in transmitter **700** employing secure communications. In step **1100**, digitized audio information is received by vocoder **704**. In step **1102**, a control signal representative of at least three speech states is generated. The three states comprise an active state, an inactive state, and a transition state.

Processing continues in one of three ways, as shown in step **1104**. If the control signal indicates an active state, processing continues to step **1106**, where an active vocoder frame is generated. Next, in step **1108**, the active vocoder frame is processed in a normal manner. In this embodiment, the active frame is

provided to encryption module **712**, state vector generator **710** is incremented, and the active vocoder frame is encrypted and stored in memory **706**.

If the control signal in step **1104** indicates an inactive state, processing continues to step **1110**, where an inactive vocoder frame is generated. Next, in step **1112**, state vector generator **710** is disabled and in step **1114**, the encryption and transmission process is prevented. In one embodiment, switch **708** is opened by the control signal thus preventing the inactive frame from being encrypted by encryption module **712**. In another embodiment, the control signal instructs a processor to disable an RF transmitter.

If the control signal in step **1104** indicates a transition from the active state to the inactive state, processing continues to step **1116**, where a transition frame is generated. The transition frame is then processed like an active frame, as shown in step **1108**, being encrypted by encryption module **712** and being transmitted to a receiver.

FIG. **12** is a flow diagram illustrating a method of controlling a discontinuous transmission process as used in receiver **700** employing secure communications. In step **1200**, encrypted vocoder frames are received and stored in receive buffer **906**.

In step **1202**, processor **914** determines whether a frame is available for decryption by decryption module **908**. If yes, processing continues to step **1204** where state vector generator **910** is enabled, thereby incrementing a state vector for use in decrypting the vocoder frame in receive buffer **906**.

In step **1206**, the encrypted vocoder frame stored in receive buffer **906** is provided to encryption module **908** for decryption using the state vector and one or more decryption keys.

In step **1208**, the decrypted vocoder frame is sent to vocoder **912** for decoding. Processing then continues back to step **1202** to determine if another encrypted frame is available for decryption.

If no frames are available in receive buffer **906**, processing continues to step **1210** where state vector generator **910** is disabled, thereby freezing the state vector in its current state. Processor **914** then instructs vocoder **912** to generate vocoder generate comfort noise in step **1212**, as specified by the last few vocoder frames successfully processed. A transmission discontinuity is preceded by several transition vocoder frames. The last few frames to be processed prior to a transmission discontinuation at transmitter **700** comprise these transition frames. The transition frames contain information pertaining to the background noise estimation occurring at transmitter **700** just prior to a transmission discontinuation. Vocoder **912** uses the information contained in

the transition frames to generate a continuous series of vocoder frames similar to the transition frames so that the output of vocoder **912** is not interrupted.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

I CLAIM: